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Research Article

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The evaluation of the production of the shaped part using the workshop programming method on the two-spindle multi-axis CTX alpha 500 lathe

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Abstract: The article deals with the description of the production of a shaped part composed of an outer pyramid and cylindrical surface, of inner cylindrical surfaces of different diameters and of an inner tongue groove. It describes the proposed tools and tool holders resulting from the technological process. In order to meet the required tolerances and shape deviations for the given component, the CTX alpha 500 two-spindle multi-axis CNC lathe was chosen for its production. Its control system enables the workshop method of programming and simulation of individual operations in automatic mode or in block-by-block mode. The design of the selected CNC lathe enables the machining of rotary parts in one clamping, which is ensured by the right and left spindle with chucks. The surface quality of the pyramidal surface and the internal diameter of D18H8 was measured using a Hommel Etamic W5 roughness gauge. The measured roughness values for the hole were: D = 18H8, Rz = 3.007 μm, Ra = 0.729 μm and for the pyramidal surface: Rz = 1.527 μm and Ra = 0.329 μm.

Keywords: CNC program simulation, two-spindle, multi-axis CNC lathe

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1 Introduction

Workshop programming was developed at the beginning of 1980 and has been extended in many areas (machining workshops in machine production facilities, maintenance workshops, prototype workshops, etc.). Workshop CNC programming is designed to address the low efficiency of manual G code programming and offline programming by means of CAM software. Good workshop programming is intuitive, simple and can easily program complex parts. Workshop CNC programming will become a very efficient programming tool for many engineering workshops and operation facilities that produce parts in small or medium-sized batches. Workshop programming has gained greater application through advances in computing. Early workshop programming operations are very similar to DOS on PCs. The user interface was text based because of hardware constraints and was not intuitive. For example, it is difficult to describe geometry in words, to force an operator to understand geometric terminology well. The design of good workshop programming for CNC machining is a challenge because many factors need to be considered. In particular, the programming software must consider a broad user base. It also needs to encompass the broad applicability of simple programming processes (such as external and internal turning or face milling) as well as complex machining processes such as multi-tool turning and auxiliary spindle (for CNC turning centres). The user interface of today's workshop programming is based on a graphical input. For example, geometric data is not only described in the text, but is also presented graphically. Therefore, the user understands the inputs intuitively and can quickly propose a work piece control program. Today's workshop programming operations are similar to Microsoft Windows operations. At present, most of the world's leading manufacturers of CNC control systems supply workshop programming systems [1]. The Japanese workshop programming program called Manual Guide i, developed and produced by GE Fanuc Figure 1, is relatively widely used. It is

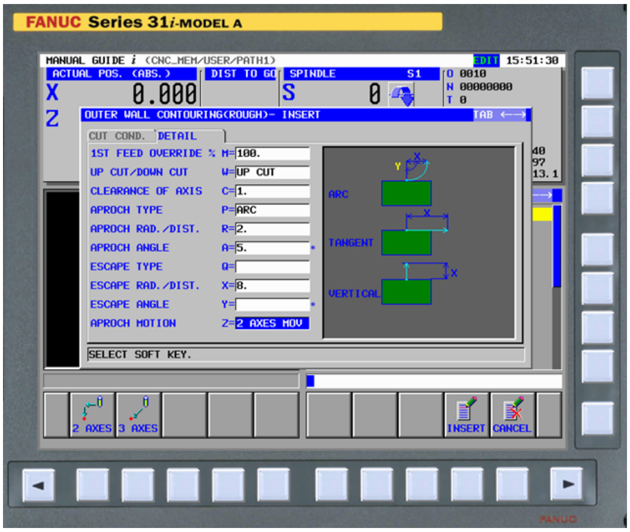

Figure 1: The preparation of CNC program by the Manual Guide i workshop programming system

modular and has a graphical user interface. It contains a basic system with turning and milling modules, which, despite different technologies, have a unified structure and user interface. The turning module initiates all cycles allowing the user to quickly and easily program the turned work piece [2].

In addition to other features, it also includes roughing and finishing functions, external and internal turning, face turning, recesses and grooving and drilling cycles. The milling module offers face milling, profile and pocket milling functions as well as drilling cycles. If applications using driven tools are used on the lathe, both modules are used. To help with the programming of lathes or milling machines, Manual Guide i also provides various fixed cycles. Graphical programming of fixed cycles is relatively simple, it is enough for the operator to fill in the graphical windows needed on the graphic CNC screen and the program is created automatically. The Siemens Company has expanded the functionality of the ShopTurn and ShopMill workshop programming software.

New features help the user to significantly reduce CNC programming time, increasing productivity in manufacturing. The technology packages are suitable for cycle driven lathes with horizontal or angled slides, horizontal or vertical turning or milling centres, as well as for complex machining centres in tool shops and mould making.

The graphic environment of the ShopTurn program now supports fully equipped rotary lathes on the milling spindle, when turning and milling tools can be used. In the milling mode, the B axis can be rotated and operated as a conventional rotary axis. The tools, such as a milling cutter or a drill, are then oriented to the B axis. The MCV 1016 Quick machine centre is a typical machine centre for the application of the JobShop - ShopMill workshop program by Siemens. It is a three-axis vertical machining centre designed for complex machining of flat and box components from metallic and non-metallic materials, or for precise manufacturing of complex parts and moulds in tool shops. The machine is controlled by the Sinumerik 810D power line CNC system in conjunction with Simodrive drives.

The new features of ShopMill system will allow helix circular pocket milling for the first time, direct rotation of the rotary axis with simple machine kinematics, and optimized rotational direction selection for rotary axes. Siemens has also developed a software workstation with the Sinutrain system, enabling the so-called "sophisticated" system. PC based training for CNC programming of the Sinumerik system and simulation of NC program operations including the JobShop workshop programming. It is a virtual simulation of machine tool operation, since the main aim of machining is to optimize the production process.

In addition to the machining itself, users are increasingly focusing on the time needed to program, align and test machine operation when evaluating machine usage. The main reason for this is that, especially in the manufacture of complex work pieces, the machine blocked for several days, with negative consequences for overall manufacturing productivity [3]. Manufacturers in the use of a “virtual machine” find improvements in this area. Another advantage is that the machining programs are tested in an environment where there is no risk of damage to the machine or tools [4]. Improvements in this area are found in the use of a “virtual machine”. Another advantage is that machining programs are tested in an environment where there is no risk of damage to the machine or tools [3]. To make the simulation easier to use in practise, it is necessary for the programmer and the machine aligner to have a machine environment display with appropriate geometry and kinematics. The “virtual machine” is based on control software for the real machine model, so in this virtual environment it is possible to precisely program, arrange the machine with virtual tools and display the actual machining process [6]. An important role in this environment is played by the implementation of the original NC core (VNCK) of the Sinumerik 840D control system in CAD / CAM software (*e.g.*, Siemens-UGS, CGTech-Vericut, Tecnomatix) [7].

Four axis machining allows all four axes to be controlled continuously, see Figure 2. All operations of a 2.5 axis but also of a 3-axis, respectively of a 3.5-axis machining can be applied to individual multi-axis machines. Each operation can be positioned according to the kinematic

Figure 2: Replacing the semi-finished product in a two-spindle four-axis lathe.

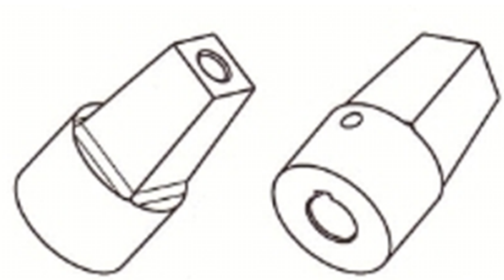

Figure 3: Model of shaped component.

possibilities of the multi-axis machine [2]. Most often, in practise, there is a 3-axis milling machine together with a continuously controlled rotary table. The fourth axis can also be the axis of rotation of the router head [8, 9]. Four axis milling can be continuous or indexed [10]. Continuous 4-axis milling is mainly used in milling centres, which have only one rotary axis and therefore a complete 5-axis milling cannot be used on them. With this continuous milling, the machine has a single rotary axis that rotates around the X, Y, or Z axis. These axes are referred to as A, B, and C [11, 12].

2 The manufacturtured component

The Figure 3 shaped component consists of an outer pyramid and cylindrical surface, inner cylindrical surfaces of different diameters, and an inner tongue groove. The component is made of C45 material. It serves as a coupling between the gearbox and the driven mechanism. One of the possible applications is also to drive hose conveyors [13–17]. The pyramidal surface serves to compensate for unevenness between the coupled mechanisms and at the same time for torque transmission [18]. On the other hand,

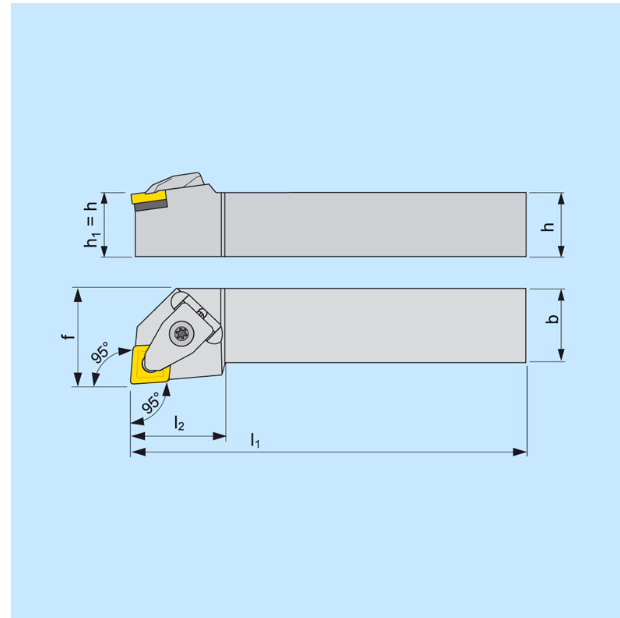

Figure 4: The DCLNR 2020 K 09 cutting plate holder [?].

the torque transmission of the coupling is provided by the tongue inserted into the coupling groove [19].

3 The suggested tools for the machining of the shaped component

When choosing the tools used in the manufacturing process on the CTX alpha 500 turning machine, the tools available were taken into account. One slotting tool, the HORN SH117.1725.1.10 and three driven tools, a ⌀16 roughing cutter, a ⌀6 finishing cutter and a ⌀7 drill were used.

The first tool used in the manufacturing process was the DCLNR 2020 K09 roughing tool with CNMG 120408E-RM Grade T9325 interchangeable cutting plates - Figure 4.

On the right-hand side of the holder, see Figure 5, there is a DCLNR 2020 K09 turning tool that processes the face and surface of the right side of the work piece. On the left side of the holder, there is the DCLNL 2020 K09 roughing tool with the replaceable CNMG 120408E-RM Grade T9325 cutting plates, which processes the face and surface of the left side of the work piece at a later stage in the process.

Another tool is the ⌀17 core drill bit DCN170-051-20A-3D, which drills the ⌀17 hole on the left side of the work piece. It is a tool with a replaceable head that is coated. It is a solid and accurate tool. A 6.5 HSS drill bit is mounted

Figure 5: Analysis of the angles on the model in graphical environment Work NC.

Figure 6: Tool holder - right side - DCN170-051-20A-3D crown drill ⌀17; left side - 6.5 HSS drill.

in the holder, which serves to connect the ⌀11 hole, which drills a drill bit with a ⌀18 hole drilled with a crown drill. These two drill bits are mounted in one tool holder, see Figure 6, to save turret space as well as for easier machine alignment.

The last tool used in the technological process is the DORMER S717 ⌀6 milling cutter Figure 7, which is used to create the R3 radius and then smooth the surface of the part to the required dimension ☐ 23 / ☐ 30.

Figure 7: Tool holder with the DORMER S717 ⌀6 finishing cutter.

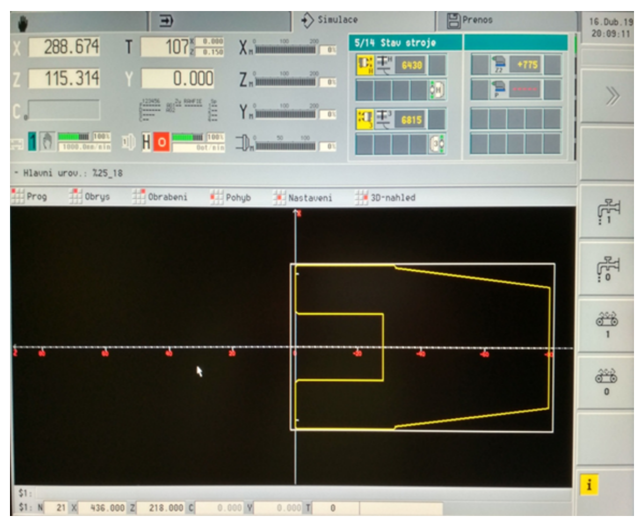

Figure 8: Definition of a semi-finished piece and zero point position.

4 NC program simulationfor the left and right part of the CTX Alpha 500 centre

When creating an NC program we have used our previous experience of permissible parameters of cutting plates and monolithic mills. When creating an NC program, a semi-finished product was defined and the coordinates of an already completed part were entered into the system, see Figure 8.

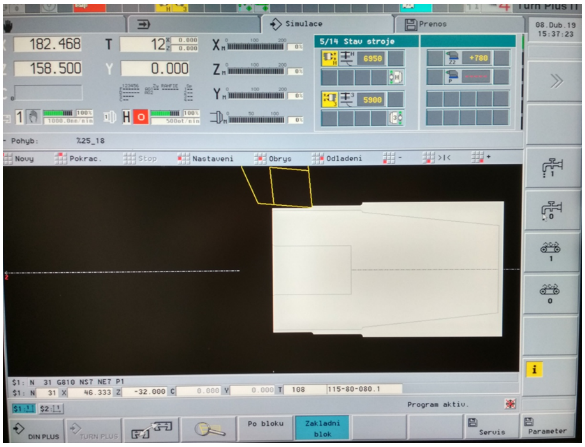

Figure 9: Turning the face and surface of the shaped part.

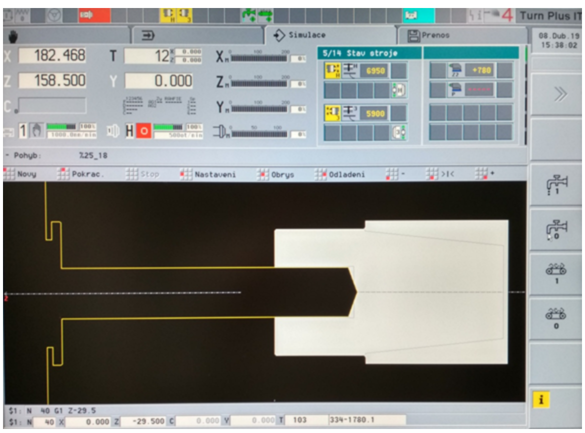

Figure 10: Drilling with ⌀17 crown drill bit.

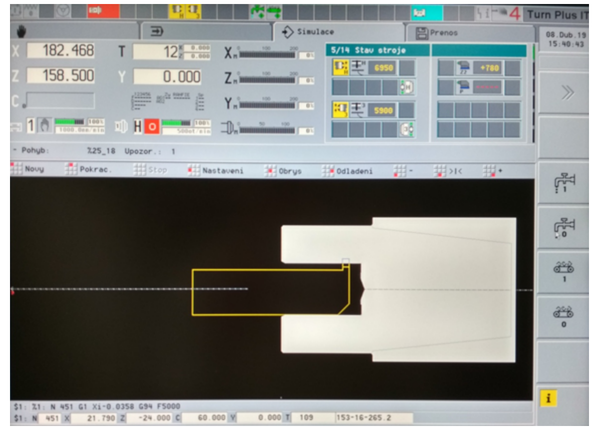

Figure 11: Slotting/shaping the groove.

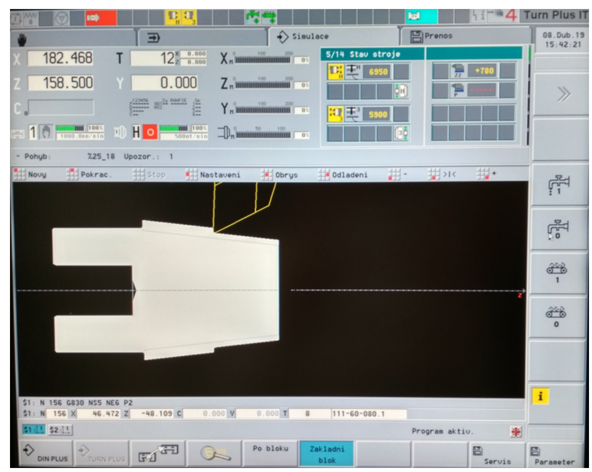

Figure 12: Roughing the cone.

The simulation starts at the right spindle - Figure 9, where the work piece machining operation is started by entering coordinates. Machining starts unusually on the right side of the spindle, usually the machining process on the main spindle side begins on the left. In this case, this method was approached due to the stronger brake on the main spindle.

In the next step of the simulation, after changing the tool to the T103 tool, which is a ⌀17 drill bit, the hole is drilled to a depth of l = 28mm - Figure 10.

After replacing the tool with the T105 tool, the simulation continues to increase the ⌀17.5 (+0.025, +0.041) hole to ⌀18. The widening of the hole to ⌀18 is performed in two steps. The hole is enlarged for the first time and then measured for a measuring cycle of ⌀17.5 (+0.025, +0.041). If an adjustment is required, it is made through the change in the correction of the tool used, which represents the second step of the hole enlargement to ⌀18 (+0.025, +0.041). In the next step of the simulation, the ⌀7 technological hole is drilled at 24mm from the work piece face. This hole will be used to let out the shaping tool in Figure 11.

The simulation continues with the grooving of the 6P9 groove to a depth of 24mm to a dimension of 20.5. For chamfering the subroutine L “1” is used with a cycle count of 99.

After the automatic reclamping of the semi-finished piece from the right spindle to the main – left

spindle, the simulation is performed by machining the work piece front and roughing the cone surface to ⌀32.5 / ⌀42.4 along the length l = 47.8-0.1 at an angle of 4° 26’51” . It cuts the edge of 1×45° on both ⌀45 and ⌀32.5. The right side of the work piece is being turned - Figure 12.

In the next step of the simulation, NC continues with the B 4.0 HSS centre drill, which pre-drills the centring hole for the ⌀6.5 HSS drill to prevent drilling out of the axis and then an edge in the hole for ⌀11 is formed. After the pre-drilling, the simulations continues with the drilling of the hole ⌀6.5 to the ⌀18 junction. It is necessary to check

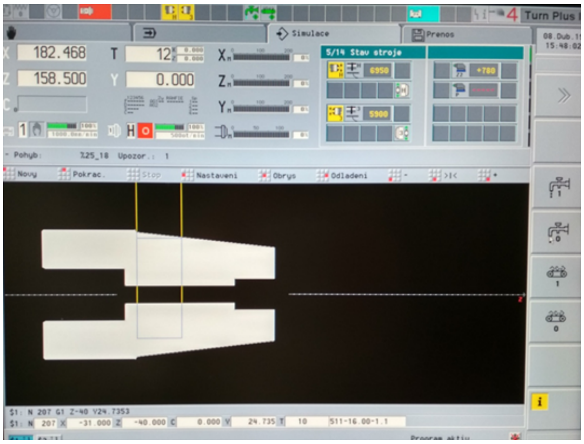

Figure 13: Roughing of the pyramid surface with a cutter D = 16.

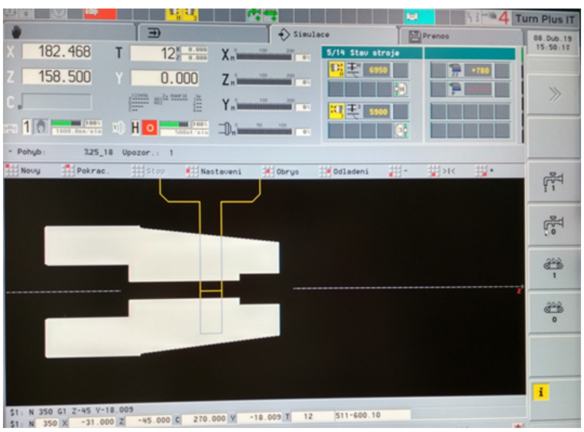

Figure 14: Finishing the pyramid surface with a cutter D = 6.

sufficient process medium pressure on the drill. A hole ⌀11 to the depth of 16 + −0.2 from the forehead is created with the help of a countersink. The next step of the simulation should be a chamfer, but such a chamfer was made in the previous step of simulation at a 60° angle.

The simulation continues with the ⌀16 roughing cutter Figure 13, which roughens the pyramid to the dimension of □ 23.2 / □ 30.2 at a length l = 45. This step is complicated by the need to position the C-axis of the spindle and the associated motion in the YZ plane.

The completion of the simulation is ensured by a ⌀6 milling cutter, which is first drilled on all 4 sides of the pyramid, creating the required radius R3 and at the same time removes and relieves excess material after the ⌀16 roughing cutter. After this, the milling cutter is positioned below the work piece axis to maintain surface finish by co-milling - Figure 14.

The four-axis CTX alpha 500 double-spindle lathe was used for the production of the shaped part with pyramidal surface, see Figure 15.

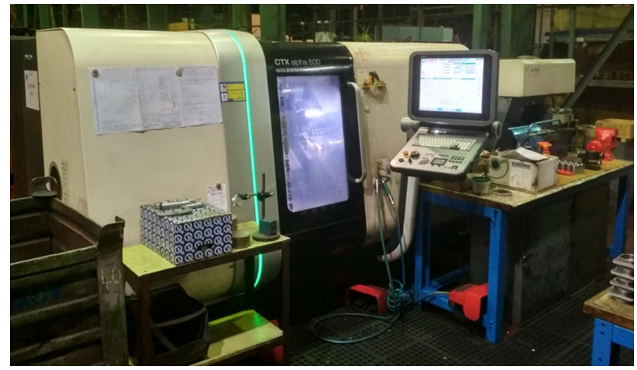

Figure 15: The CTX alpha 500 four axis double spindle lathe.

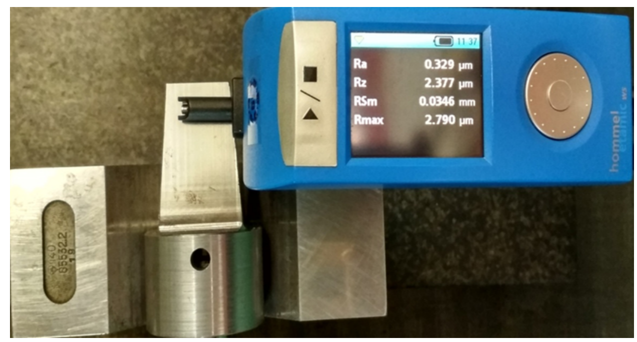

Figure 16: Surface roughness measurement by means of the Hommel Etamic W5 roughness tester.

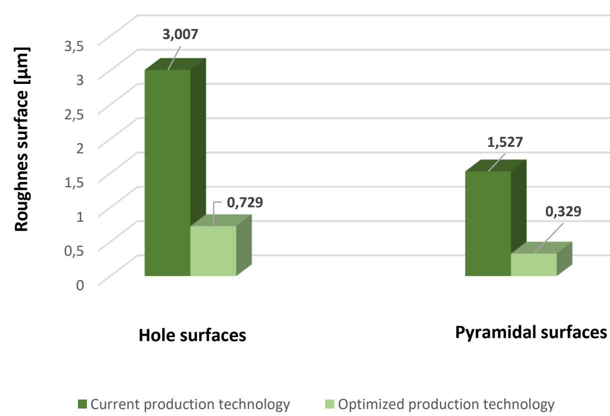

Figure 17: The measured roughness values on the outer pyramidal and inner cylindrical surfaces.

4.1 Surface quality assessment of shaped part

The Hommel Etamic W5 roughness gauge - Figure 16 - was used to measure the surface roughness.

The measured roughness values on the outer pyramidal and inner cylindrical surfaces are shown in Figure 17.

5 Discussion

The type of multi-axis twin-spindle cnc turning machine was chosen according to the shape of the model component itself. The workshop programming method for a given component shape is simpler than the CAM programming method, which is executed more directly by the machine operator that perfectly controls it.

6 Conclusion

Workshop programming is more suitable for operation facilities that produce a wide range of parts in single piece and small batch production. In these operations, the operator will often have to create a control program, select tools and clamping method and verify and optimize the control program created. Workshop programming can significantly increase manufacturing productivity in these facilities. For machines for simultaneous machining such as *e.g.* turning centres, workshop programming was not successful in the past. End users will certainly consider using workshop programming on these machines as well. Workshop programming is very beneficial in providing CNC training. The training function can help operators get a better understanding of CNC programming and CNC operations. Well trained CNC operators can greatly improve machine performance. Future workshop programming will have more of the Microsoft Windows graphical operating system, and both the input and editing of the control program will become more convenient. Features widely used in today's unsupported CAM software, *e.g.* three-dimensional graphical interpretation, can be combined in a conversational programming system. Some exclusive workshop programming software will also operate in the field of parallel machine programming. The mean arithmetic values for the hole D = 18H8, Rz = 3.007 μm, Ra = 0.729 μm for the pyramidal surface Rz = 1.527 μm and Ra = 0.329 μm were determined by measuring. The selected programming method, tools and cutting conditions are satisfactory.

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